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# Effect of Opening Size and Location on the Shear Strength Behavior of R.C Deep Beams without Web Reinforcement

HawrazKarim M. Amin, V.C. Agarwal, Omar Q. Aziz

*Abstract- This paper is carried out to study the effect of opening Sizes and Locations on the Shear strength behavior of reinforced concrete deep beams without web reinforcement, the opening size and location were main factors included in the present work, Variation of Parameters (l/d, a/d, fc and maximum size of aggregate) which affect the behavior of R.C deep beams are taken into account, a nonlinear analysis using the finite element method with (Ansys+CivilFEM) release 12.0 program was used to predict the ultimate Shear and mode of failure for reinforced concrete deep beams with openings, Materials nonlinearities due to cracking, crushing of concrete and yield conditions of the reinforcing steel are considered. The capabilities of the proposed model have been examined and demonstrated by analyzing available experimental eleven reinforced concrete deep beams without openings which showed a good agreement with difference for ultimate Shear a bout (6.4%), then after validation the program 99 models were created with square web openings having 3 sizes at 3 locations in each model to study their effect on the shear stress, (Ansys+CivilFEM) software was found completely efficient in handling such analysis and the proposed simulation of the material in the present study are capable of Predicting the behavior of reinforced concrete Deep Beams with Openings of Different Sizes and Locations, the results showed that location of openings has a large effect, where this effect is the largest when openings is provided at shear zone where sharp decrease in the ultimate Shear was observed and Mid-span location showed small effect and the ultimate Shear increases with decrease for the size of openings. The effect of parameters (l/d, a/d, fc, and maximum size of aggregate) are observed where changing l/d from 2.42 to 8.4 and (a/d) from 1 to 2.5 has high significant effect in decreasing the shear strength but increasing (a/d) from 1.5 to 2.25 for (l/d) of 4.61 and maximum size of aggregate from 9.5mm to 19mm has a very little effect while increasing the compressive strength of concrete increases the ultimate Shear Strength in different rates for varied opening locations and sizes.*

*Keywords-deep beams, web opening effect, Shear strength behavior, (Ansys+CivilFEM)*

## I. INTRODUCTION

For reinforced concrete, improvement of calculation methods and analysis of behavior or by either creating a model on computer or counting with analytical calculation methods are used extensively in recent years.

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The behavior of a reinforced concrete element is generally observed by conducting experiment on laboratory environment; but this process considerably takes up much time. The studies are limited due to the problems in providing the materials and the proper conditions to conduct the experiments and scarcity of usage of materials which are constituted according to certain size and number of elements. Modeling of all these Processes unlimitedly in computer is dependent on the capacity of the computer being used. While modeling on the computer, properties and limit conditions of materials should be defined properly and completely [12].

Finite element method is a numeric method which can solve complex and difficult physical problems) with acceptable approximation. As concrete is a material showing nonlinear behavior during loading, it is modeled in such a way that it will show a nonlinear behavior with (Ansys+CivilFEM) finite element program which is the most advanced comprehensive reputable finite element analysis and design software package available for Structural Engineering Projects. The System combines the state of the art general propose structural analysis features of ANSYS with the high and civil engineering specific structural analysis capabilities of CivilFEM, making it a unique and powerful tool for a wide range of civil engineering projects [7].

Deep beam is a fairly common structural element in tall buildings, offshore structures and in foundations systems; it is recognized by relatively small values of span-to-depth ratio. As per code provisions given by American Concrete Institute (ACI 318-05) a beam shall be considered as deep beam when the ratio of effective span to overall depth ratio is less than 4.0 or regions with concentrated loads within twice the member depth from the face of the support [13]. The openings are usually provided in such beams to have an access for utility ducts like air conditioning, electricity or a computer network without further increases in ceiling head room.

## II. REVIEW OF LITERATURE

**Sultan(2003)**[16] used the results of testing 261 deep beams, 106 of which were without web reinforcement and the others with vertical or horizontal stirrups or both. The main variables were the shear span to depth ratio (a/d), longitudinal reinforcement ratio, concrete compressive strength and vertical and horizontal web shear stress reinforcement. Test results showed that, for beams with a/d≤ 2.5, these variables had a significant effect on the ultimate shear strength of these beams.


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It was also found that the ultimate shear strength increases significantly with increasing concrete compressive strength and longitudinal reinforcement ratio, and with decreasing shear span to effective depth ratio.

**J.K Lee, C.G. Li and Y.T. Lee(2008)** [10] tested R.C Continuous Deep Beams to evaluate the Shear Strength with Various Location of Web Opening, In total 5 specimens with circular web opening have been cast and tested in the laboratory it has been observed that the specimens with web opening have about 90% of Shear Strength of the specimen without web opening, In General the Span with web opening is less Stiff than have the span without web opening. Web opening in the Deep Beam with Shear span-Depth ratio of 1.0 can be located not in the compressive Strut area but tensile area in this case adequate reinforcement should be provided around the opening to avoid the Crack Width wider and Fail and the Shear Strength of Deep Beams with web opening whose diameter is 0.3 times op depth is 87-92% of rest result of deep beam without opening.

**Giuseppe Campione and Giovanni Minafo (2012)**[6]studied Behaviour of concrete deep beams with openings and low shear span-to-depth ratio twenty reinforced concrete small-scale deep beams with or without openings were tested in flexure under four-point loading. The beams had a small shear span-to-depth ratio in order to stress the shear behavior. The specimens had different reinforcement arrangements and opening positions. The load was transmitted to the specimen with bearing plates having the same side length as the beam. A device was mounted to measure the middle deflection of the beam. Comparative analysis of the experimental results shows that: the effect of the hole depends on its position in the beam; the benefit of the presence of reinforcement depends on its arrangement. An analytical model is proposed to predict the shear strength and corresponding deflection of deep beams with openings and the results are also compared with a non-linear finite element analysis showing good agreement.

**Haider M. Alsaeq (2013) [8]**investigated the effects of the opening shape and location on the structural behavior of reinforced concrete deep beam with openings, while keeping the opening size unchanged. The software ANSYS 12.1 is used to handle the nonlinear finite element analysis. The ultimate strength of reinforced concrete deep beam with opening obtained by ANSYS 12.1 shows fair agreement with the experimental results, with a difference of no more than 20%. The present work concludes that the opening location has mu effect on the structural strength than the opening shape. It was concluded that placing the openings near the upper corners of the deep beam may double the strength, and the use of a rectangular narrow opening, with the long sides in the horizontal save up to 40% of structural strength of the deep beam.

## III. RESEARCH SIGNIFICENSE

In the last few years a good deal of work has been done on openings in deep beams. As the usage of those beams increases, it becomes imperative to Study behavior of such beams in diversity cases and main factors included in the problem such as shear span-to-depth ratio, cross sectional properties, amount, type and location of web reinforcement, concrete strength, size, shape and location of web opening. In the present work the opening Size was studied as well as Opening location to obtain the optimal results while the Shape is fixed.

## IV. MODEL GENERATION

In ANSYS terminology, the term model generation usually takes on the narrower meaning of generating the nodes and elements that represent the spatial volume and connectivity of the actual system. Thus, model generation in this discussion will mean the process of defining the geometric configuration of the model's nodes and elements [4].From the available element library in ANSYS, the elements used in this work are: “SOLID65” for Concrete, “SOLID45” for Steel plates and “LINK8 for Steel reinforcement, which has properties as:

### A. *SOLID65 Element Description*

SOLID65 (or 3-D reinforced concrete solid) is used for the 3-D modeling of solids with or without reinforcing bars (rebar) Figure (1). The solid is capable of cracking in tension and crushing in compression. In concrete applications, for example, the solid capability of the element may be used to model the concrete, while the rebar capability is available for modeling reinforcement behavior. Other cases for which the element is also applicable would be reinforced composites (such as fiberglass), and geological materials (such as rock). The element is defined by eight nodes having three degrees of freedom at each node: translations of the nodes in x, y, and z-directions. Up to three different rebar specifications may be defined[4].

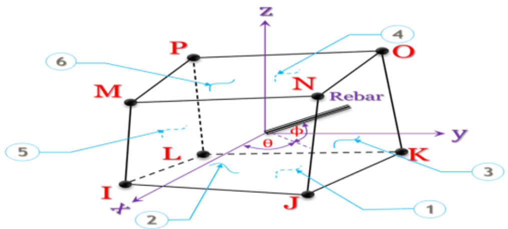


Figure (1): element (SOLID65) geometry

### B. *SOLID45 Element Description*

An eight node solid element, SOLID45, was used for steel supports in the beam models. The element is defined with eight nodes having three degrees of freedom at each node translations in x, y and z directions [3]. The geometry and node location for this element type are shown in Figure (2). Steel plates were added at support and point of loading locations in the finite element models (as in the actual beams) to provide a more even stress distribution over the support and point of loading areas. An elastic modulus equal to 200000 MPa and Poisson’s ratio of 0.3 were used for the plates. The steel plates were assumed to be linear elastic materials [2].

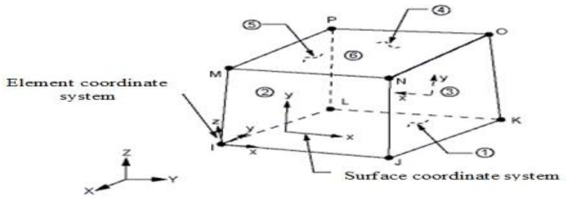


Figure (2): element (SOLID45) geometry


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### *C. LINKE8 Element Description*

LINK8 is a spar (or truss) element which may be used in a variety of engineering applications. This element can be used to model trusses, sagging cables, links, springs, etc. The 3-D spar element is a uniaxial tension-compression element with three degrees of freedom at each node: translations of the nodes in x, y, and z-directions. As in a pin-jointed structure, no bending of the element is considered. Plasticity, creep, swelling, stress stiffening, and large deflection capabilities are included. This element is used, in this study, to simulate the behavior of steel reinforcement which works as main steel reinforcement in resisting the flexural stresses [9]. The geometry, node locations, and the coordinate system for this element are shown in figure (3).

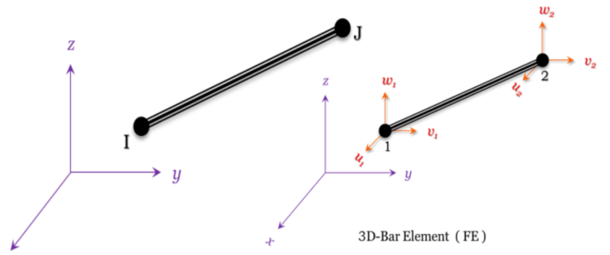


Figure (3):element (LINK8) geometry

## V. MODELING OF MATERIAL PROPERTIES

An important aspect of any finite element analysis is to model the constitutive material properties. The model should be correctly describing the behavior of the material under uniaxial and multiracial states of loading; Follow up is the constitutive relationships description of materials and Structural components.

### *A. Concrete*

For concrete, ANSYS computer program requires input data for material properties, as follows [11]:

- Elastic modulus ($E_c$).
- Ultimate uniaxial compressive strength ($f_c'$)
- Ultimate uniaxial tensile strength (modulus of rupture,$f_r$)
- Poisson's ratio (ν)
- Shear transfer coefficient for opened and closed cracks($\beta_{\circ}$ and$\beta_c$)respectively.
- Compressive uniaxial stress-strain relationship for concrete.

An effort was made to estimate the ultimate uniaxial compressive and tensile strength ($f_c'$ and$f_r$) of test reinforced concrete beams. Details about these values and others, related with mechanical properties of concrete

The modulus of elasticity of concrete ($E_c$) is generally taken to be a function of the compressive strength ($f_c'$) with a slightly higher value of the modulus corresponding to a higher compressive strength. In lieu of actual test data, the modulus of elasticity can be calculated with a reasonable accuracy according to ACI committee 318 [1] from the empirical formula:

$$E_c = 0.043(w_c)^{1.5}(f_c')^{0.5}$$

Where:

$w_c$: Air- dry unit weight of concrete in ($Kg/m^3$)
$f_c'$: Cylinder compressive strength of concrete in (MPa)
$E_c$: Concrete modulus of elasticity in (MPa)

For normal weight concrete based on a dry unit weight (2200- 2500 kg/m3),$E_c$ can be permitted to be taken as follow which is used in current study:

$$E_c = 4700\,(f_c')^{0.5}$$

Poisson's ratio (ν) of concrete has been observed to remain approximately constant and ranges from about 0.15 to 0.22 up to a stress. Beyond this level, Poisson's ratio increases rapidly.

For current study Poisson's ratio for concrete was assumed to be 0.2 for all reinforced concrete Deep beams.

The shear transfer coefficient, β, represents conditions of the crack face. The value of β ranges from 0.0 to 1.0, with 0.0 representing a smooth crack (complete loss of shear transfer) and 1.0 representing a rough crack (no loss of shear transfer) [3]. The shear transfer coefficients used in this study were 0.4 for an open crack and 0.6 for a closed crack for all strengthened beam specimens.

### *B. Steel*

In (Ansys+Civil FEM) program Stress- Strain curve has four points as in figure (4) and there values are calculated as follow:

$$\varepsilon_1 = -0.01$$

$$\varepsilon_2 = -f_y/E_s$$

$$\varepsilon_3 = f_y/E_s$$

$$\varepsilon_4 = \ \ 0.01$$

$$\sigma_1 = -f_y + \frac{-0.01 + f_y/E_s}{P_r/E_s}$$

$$\sigma_3 = -f_y$$

$$\sigma_3 = \ \ f_y$$

$$\sigma_4 = \ \ f_y + \frac{0.01 - f_y/E_s}{P_r/E_s}$$

Where:

$P_r$ = elasticity to plasticity coefficient proportion [5]

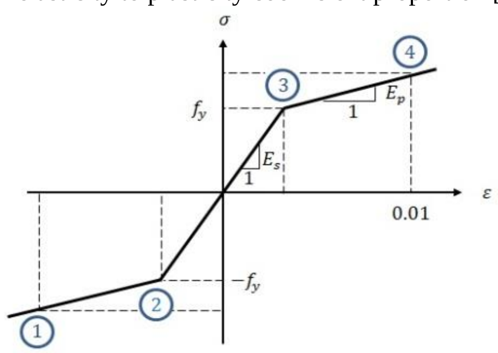


Figure (4): Stress-Strain curve for Steel in Tension and Compression


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## VI. NONLINEAR SOLUTION

ANSYS employs the "Newton-Raphson" approach to solve nonlinear problems. In this approach, the load is subdivided into a series of load increments. The load increments can be applied over several load steps. [3].

To summarize, a nonlinear analysis is organized into three levels of operation:

- The "top" level consists of the load steps that are defined explicitly over a "time" span. Deflections are assumed to vary linearly within each load step (for static analyses).
- Within each load step, the program can be directed to perform several solutions (sub steps or time steps) to apply the load gradually.
- At each sub step, the program will perform a number of equilibrium iterations to obtain a converged solution.

## VII. ANALYSIS TERMINATION

The efficiency of a nonlinear solution method can be measured by its "order of termination"

ANSYS' automatic solution control sets the value of (Number of Equilibrium Iteration) to between 15 and 26 iterations, depending upon the physical condition of the problem. The idea is to employ a small load step with less quadratic-ally converging iteration.

This option limits the maximum number of equilibrium iterations to be performed at each sub step (default = 25 if solution control is off). If the convergence criteria have been satisfied within this number of equilibrium iterations, the analysis will attempt to bisect. If bisections is not possible, then the analysis will either terminate or move on to the next load step. The maximum numbers of iterations used in this study are 75.

## VIII. VARIABLES AND SPECIMEN DETAILS

99 Deep Beam models without Web Reinforcement was Created By (Ansys+CivilFEM) program with Different Openings, Square Openings was made in Different Sizes and Locations, 3 Sizes of Openings was taken as a Variable with proportions from Beam Height (h) which were (0.45h, 0.30h and 0.15h), Three Locations used for openings (Shear zone, Support and Mid-Span) of the beam, the Eleven Cases of solid Deep Beams without web reinforcement with Different Dimensions and Parameters Studied By (Aziz and Abdul-Ahad 2012) [15], were used to show the effect of openings.Details the opening Sizes and LocationsShown in Figures (5), (6) and (7)

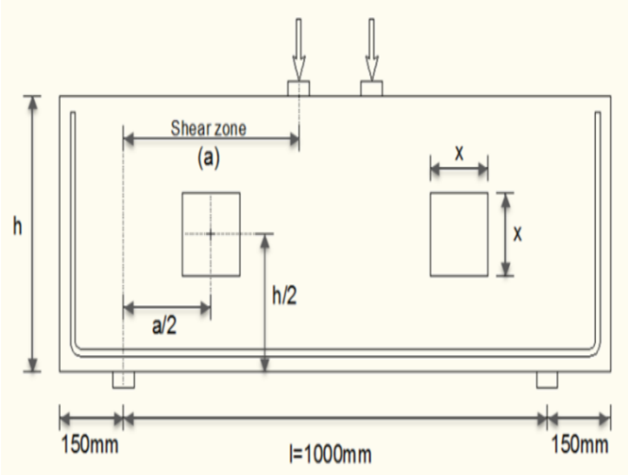


Figure (5): Detail of Deep beam with Opening at Shear zone

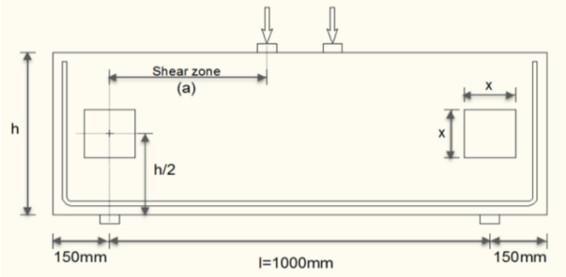


Figure (6): Detail of Deep beam with Opening at Support

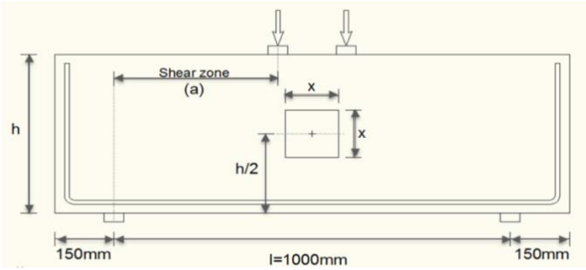


Figure (7): Detail of Deep beam with Opening at Mid-span

Where: (x) is opening dimension which are (0.45h) or (0.30h) or (0.15h)

## IX. VALIDATION OF FEM COMPUTER PROGRAM

(O. Q. Aziz and R. B. Abdul-Ahad 2012) tested 11 crushed stone reinforced concrete Deep beams without web reinforcement All the tested beams were rectangular in cross-section having the dimensions (b=120, l=1000) mm. The overall depth varied from 150 to 450 mm to get the required l/d and a/d ratios. Figure (8) and Table (1) give details of the tested beams. Each beam is identified by the label, SXN, where the letter (SX) denotes the test series; (N) denotes the number of the tested beam. [15].


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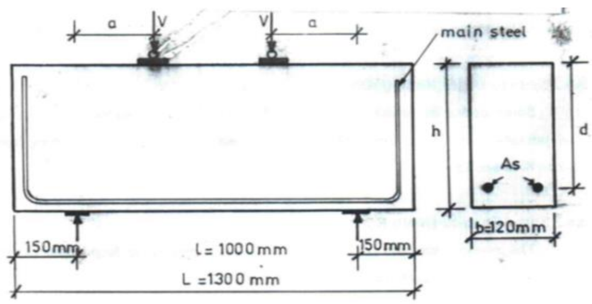

Figure (8): Detail of the crushed stone concrete deep beams without shear Reinforcement

Table (1): Detailed of the tested crushed stone concrete deep beams

| Name of specimen | h (mm) | b (mm) | d (mm) | (l/d) ratio | (a/d) ratio | fc (MPa) | Dagg. (mm) | Long. As | fy (MPa) |
|---|---|---|---|---|---|---|---|---|---|
| S1-1 | 450 | 120 | 414 | 2.42 | 1 | 30.85 | 9.5 | 3Ø22 | 430 |
| S1-2 | 350 | | 313 | 3.2 | 1.25 | 29.36 | 9.5 | 2Ø25 | 395 |
| S1-3 | 250 | | 217 | 4.61 | 1.5 | 29.24 | 9.5 | 3Ø16 | 486 |
| S1-4 | 150 | | 119 | 8.4 | 2.5 | 26.25 | 9.5 | 3Ø12 | 416 |
| S1-5 | 350 | | 313 | 3.2 | 1.25 | 42.3 | 9.5 | 3Ø16 | 486 |
| S1-6 | 250 | | 217 | 4.61 | 1.5 | 43.5 | 9.5 | 3Ø16 | 486 |
| S1-7 | 250 | | 217 | 4.61 | 1.5 | 32.07 | 12.5 | 3Ø16 | 486 |
| S1-8 | 250 | | 217 | 4.61 | 1.5 | 31.81 | 19 | 3Ø16 | 486 |
| S1-9 | 250 | | 217 | 4.61 | 1 | 32.86 | 9.5 | 3Ø16 | 486 |
| S1-10 | 250 | | 217 | 4.61 | 2 | 33.23 | 9.5 | 3Ø16 | 486 |
| S1-11 | 250 | | 217 | 4.61 | 2.25 | 28.9 | 9.5 | 3Ø16 | 486 |

Where: Dagg. Refers to maximum size of aggregate

### A. *Finite Element Mesh (Modeling)*

A convergence study on full model of the beams was carried out to determine an appropriate mesh density Figures (9) and (10) shows a typical finite element model for the beam specimen and reinforcement.

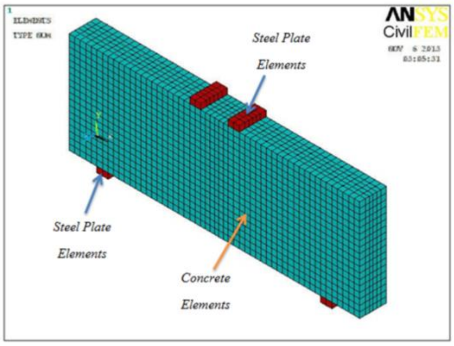

Figure (9): Typical Finite Element model and Elementsused for the beam specimen

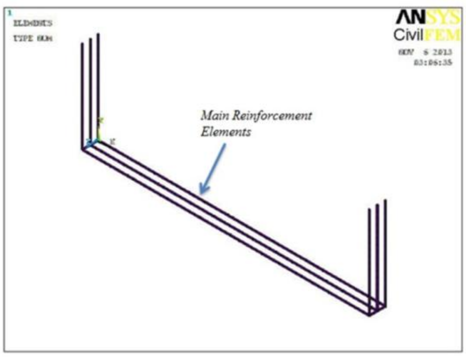

Figure (10): Typical Finite Element model and Elementsused for the Steel Reinforcement

### B. *Loading and Boundary Conditions*

A one-cm thick steel plate, modeled using Solid45 elements, was added at the support and point of loading locations in order to avoid stress concentration problems, a single line support was placed under the centerline of the steel plate to allow rotation of the plate. Figures (11) and (12) show the applied load and boundary conditions, the applied load on it will be equal to the total applied load. Figure (13) shows the distribution of applied load at nodes.

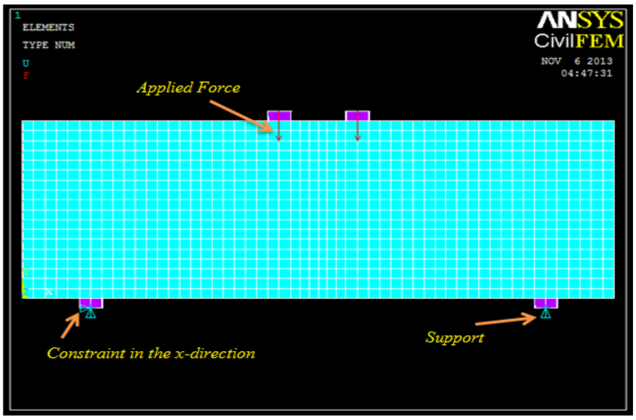

Figure (11): Applied load and boundary conditions (Front view)

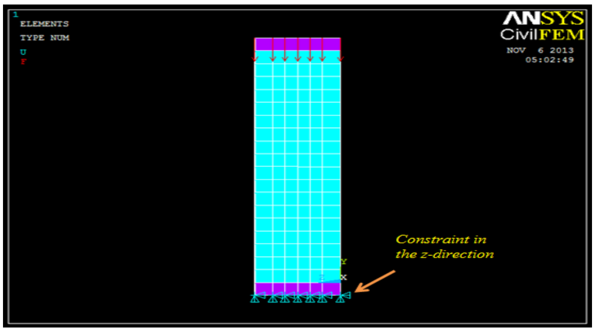

Figure (12): Applied load and boundary conditions (Side view)

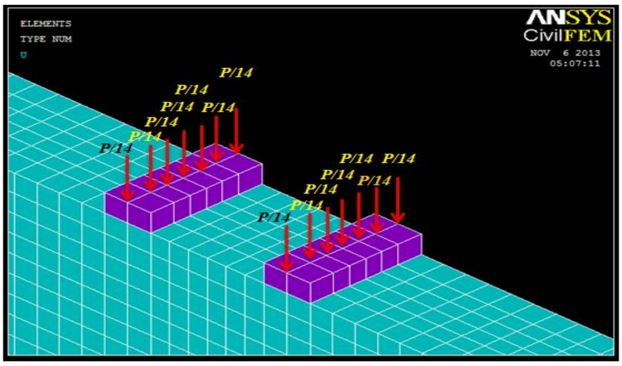

Figure (13): Distribution of applied load at nodes

### C. *Results from Finite Element Analysis*

The results from (Ansys+CivilFEM) finite element analysis were compared with the experimental data. The following comparisons are made: Shear-Deflection curves at Mid-Span, failure Shear


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- ***Shear Stress-Deflection Curves***

Dial gage was used to measure deflections for the experimental beams at mid-Span at the center of the bottom face of the beams. For (ANSYS+CivilFEM), deflection was measured at the same location as for the experimental beams and The Shear Stress (v=p/2bd) versus Deflection for each beam was plotted. Figures (14) to (24) show the Shear Stress-Deflection curves from the finite element analysis and the experimental results which showed that the curves from the finite element analysis agreed well with the experimental data.

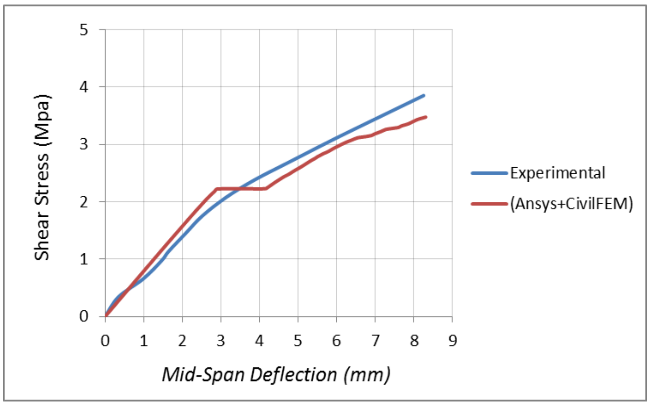


Figure (14): Shear-Deflection curve of Beam (S1-1)

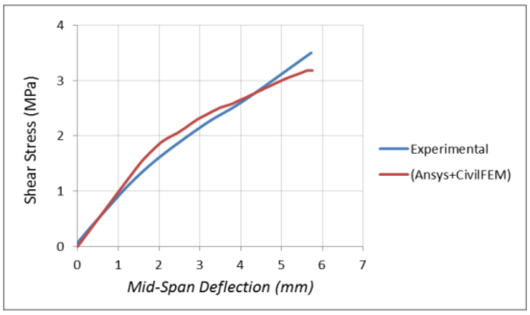


Figure (15): Shear-Deflection curve of Beam (S1-2)

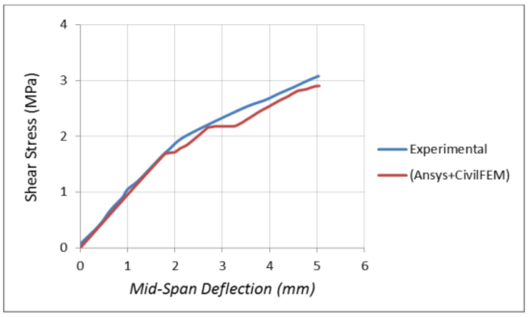


Figure (16): Shear-Deflection curve of Beam (S1-3)

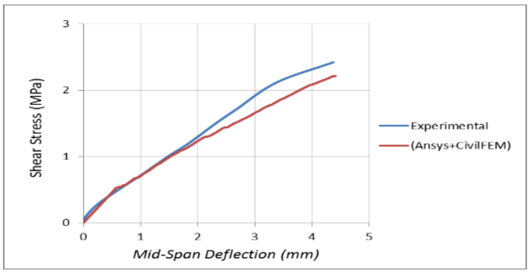


Figure (17): Shear-Deflection curve of Beam (S1-4)

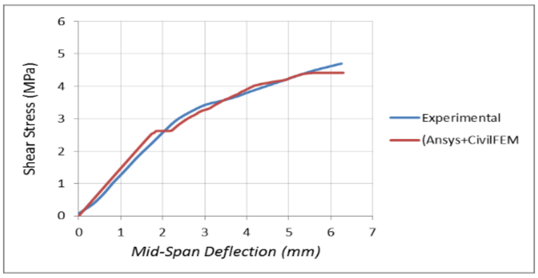


Figure (18): Shear-Deflection curve of Beam (S1-5)

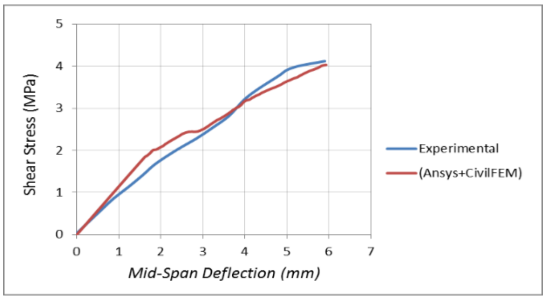


Figure (19): Shear-Deflection curve of Beam (S1-6)

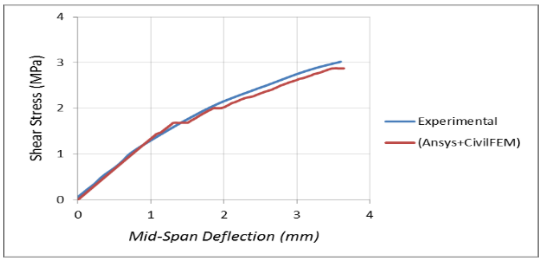


Figure (20): Shear-Deflection curve of Beam (S1-7)

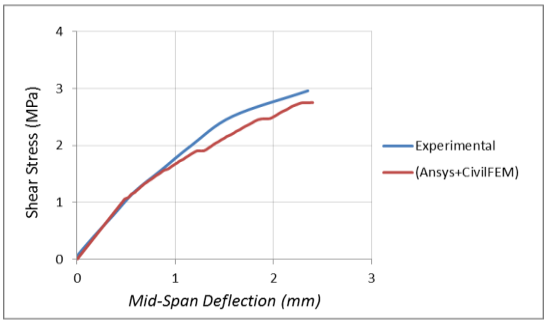


Figure (21): Shear-Deflection curve of Beam (S1-8)

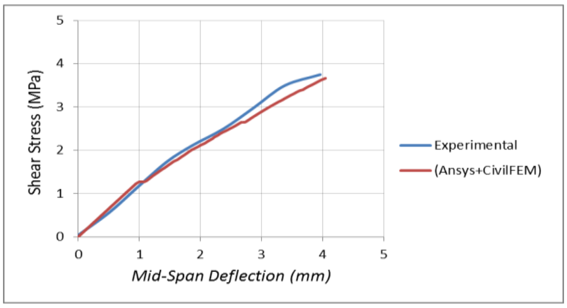


Figure (22): Shear-Deflection curve of Beam (S1-9)



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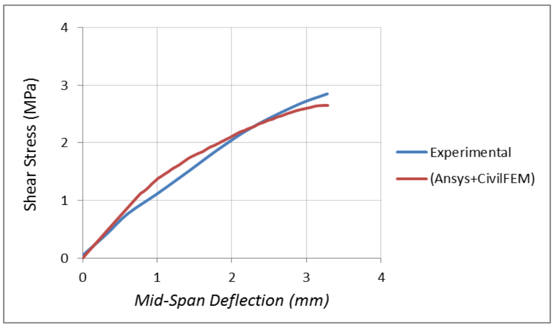


Figure (23): Shear-Deflection curve of Beam (S1-10)

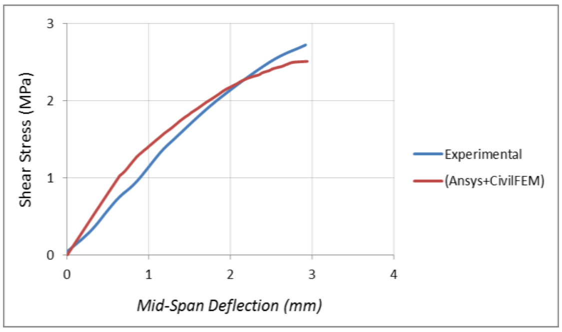


Figure (24): Shear-Deflection curve of Beam (S1-11)

- ***Experimental and Numerical Ultimate Shear Stress***

A comparison between the ultimate Shear Stress of the tested beams and numerical ultimate Shear from finite element analysis is shown in Table (2). The table shows the failure Shear Stress for each Beam. The failure of the modeled beams was indicated by the state that the beam no longer can support additional load as indicated by the convergence failure of (ANSYS+CivilFEM) program in failing to find a solution. a good agreement between the theoretical and experimental results is observed, The average difference of ultimate Shear between experimental and (ANSYS+CivilFEM) program was (6.4%) for all the tested and analyzed beams.

Table (2): Comparison between experimental and Numerical ultimate Shear

| *Name of specimen* | *Experimental Vu (Mpa)* | *Numerical Vu (Mpa)* | *(Vu) Exp. / (Vu) Num.* | *Difference (%)* |
|---|---|---|---|---|
| S1-1 | 3.85 | 3.47 | 1.11 | -9.87 |
| S1-2 | 3.50 | 3.18 | 1.10 | -9.14 |
| S1-3 | 3.08 | 2.90 | 1.06 | -5.84 |
| S1-4 | 2.42 | 2.21 | 1.10 | -8.68 |
| S1-5 | 4.70 | 4.42 | 1.06 | -5.96 |
| S1-6 | 4.12 | 4.03 | 1.02 | -2.18 |
| S1-7 | 3.02 | 2.87 | 1.05 | -4.97 |
| S1-8 | 2.96 | 2.75 | 1.08 | -7.09 |
| S1-9 | 3.75 | 3.67 | 1.02 | -2.13 |
| S1-10 | 2.85 | 2.65 | 1.08 | -7.02 |
| S1-11 | 2.72 | 2.51 | 1.08 | -7.72 |

## X. MODELING OF THE DEEP BEAM WITH OPENINGS

After Validation the input data and material properties of the models created for the experimental example and comparing results of the finite element Analysis with the actual Deep Beams we used (Ansys+CicilFEM) program to study the effect of making openings in the same Deep Beams of (O. Q. Aziz and R. B. Abdul-Ahad 2012) with Difference Opening Sizes and Locations and study there effect on the shear strength behavior with the same parameters (l/d, a/d, fc and maximum size of aggregate) The 99 Deep Beams was Modeled with the same geometrics and Details which shown Table (1) but in variations opening size and location for each beam, Material Properties used for Modeling as Shown in Figures (9) and (10), Loading and Boundary Condition, Distribution of applied load at nodes as in Figures (11), (12) and (13), The opening locations are Shown in following figures:

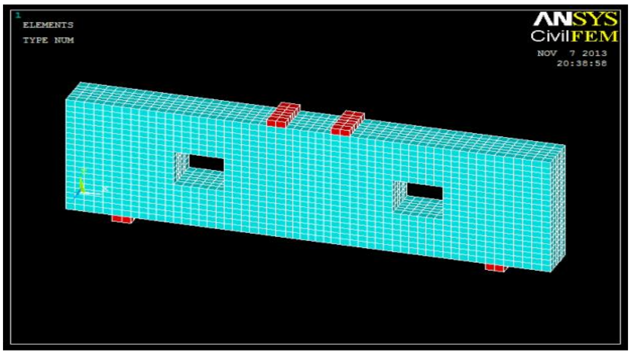


Figure (25):Typical Model for Deep Beam with Opening at Shear zone Location

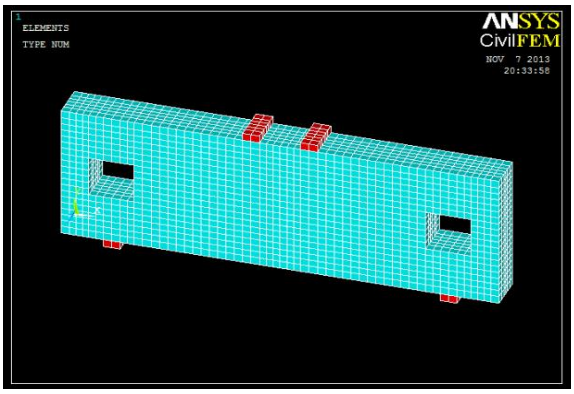


Figure (26): Typical Model for Deep Beam with Opening at Support Location

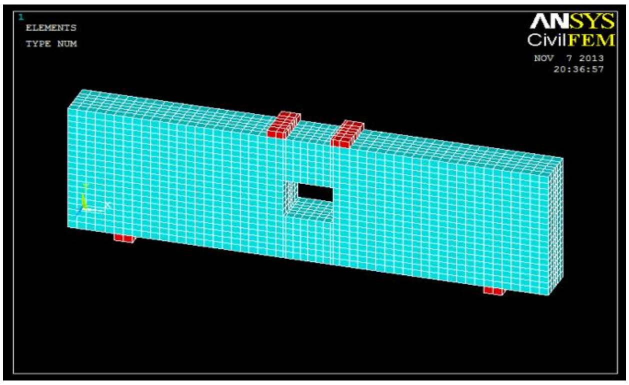


Figure (27): Typical Model for Deep Beam with Opening at Mid-Span Location


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### *A. Results of the Deep Beams with Opening*

Finite element non-linear analysis of the 99 Deep Beams with Opening Showed an acceptable results a comparison was made with the Numerical results Described in Table (2) for the 11 Deep beam models without Openings created by (Ansys+CivilFEM) to study the effect of openings in comparison with the same beam but without opening to Show the effect of creating openings in actual beam with variable opening Sizes and Locations, the results showed that Providing an opening at the shear zone causes sharp decrease in the ultimate Shear by about (53.6%) and when opening is located at the Supports the average reduction in Shear Stress is (23.93%) but the Mid-Span location showed the minimum effect where the average reduction in Shear Stress is (8%), and when Creating Square openings with dimensions (0.45h x 0.45h) makes the average reduction in Shear Stress about (45.78%) and the Dimensions (0.30h x 0.30h) the average reduction in Shear Stress is (28.2%) but the Size (0.15h x 0.15h) showed the less effect where the average reduction in Shear Stress is (11.55%)

### *B. Effect of Compressive Strength of Concrete ($f'_c$)*

increasing fc from 30MPa to 43MPa for maximum size of aggregate of 9.5mm when (a/d) is 1.5 and (l/d) is 4.61 the average increment in the shear stress are (46.73%, 41.04% and 24.69%) for shear zone, support and mid-span opening locations respectively and (46.63%, 37.8%, 31.03%) for Sizes (0.45h x 0.45h), (0.30h x 0.30h) and (0.15h x 0.15h) respectively.

While for (a/d) of 1.25 and (l/d) of 3.2 the average increment in the shear stress are (72.07%, 60.74% and 47.22%) for shear zone, support and mid-span opening locations respectively and (72.59%, 57.32%, 50.12%) for Sizes (0.45h x 0.45h), (0.30h x 0.30h) and (0.15h x 0.15h) respectively.

Effect of parameters (l/d, a/d, and maximum size of aggregate) were discussed and presented in Figures (28) to (45)

Where:

A, S and M refers to Shear zone, Support and Mid-span Opening locations respectively

**45**, **30** and **15** refers to (0.45h x 0.45h), (0.30h x 0.30h) and (0.15h x 0.15h) Opening Sizes respectively as follow:

### *C. Effect of Span to Depth Ratio (l/d)*

Ultimate Shear Stress increased by decreasing (l/d) ratio but in different rates depends on opening locations and sizes, where increasing (l/d) ratio from 2.42 to 8.4 for (a/d) between (1 and 2.5) and maximum size of aggregate of 9.5 reduces the shear stress by about (28.46%, 32.26% and 41.4%) for shear zone, support and mid-span opening locations respectively and (26.33%, 38.47%, 37.32%) for Sizes (0.45h x 0.45h), (0.30h x 0.30h) and (0.15h x 0.15h) respectively, Figures (28) to (33) represents shear stress versus span to depth ratio (l/d) curves which used to show the effect of opening sizes and locations as follow:

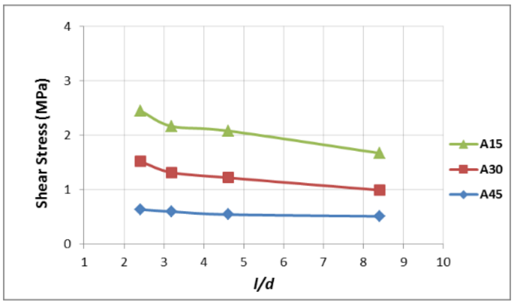


Figure (28): Effect of Opening Size at Shear zone

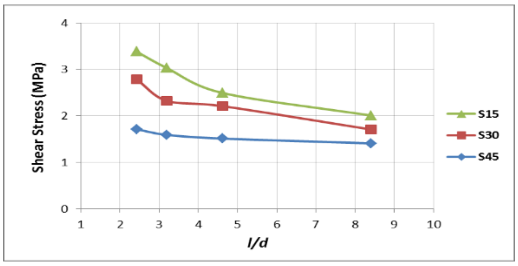


Figure (29): Effect of Opening Size at Support

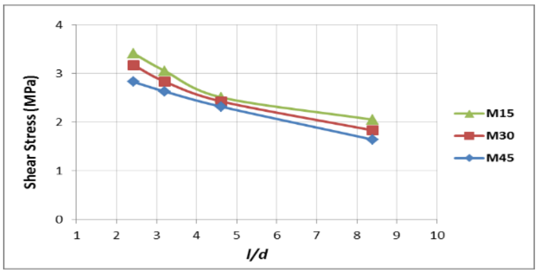


Figure (30): Effect of Opening Size at Mid span

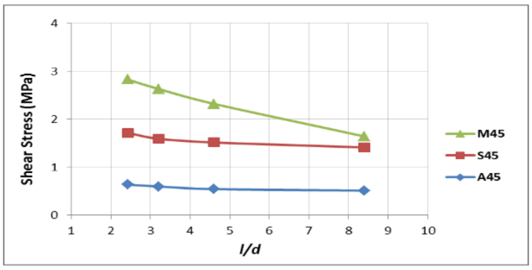


Figure (31): Effect of Opening Location with Size (0.45h x0.45h)

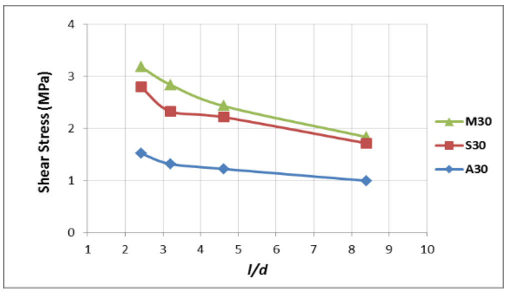


Figure (32): Effect of Opening Location with Size (0.30h x 0.30h)



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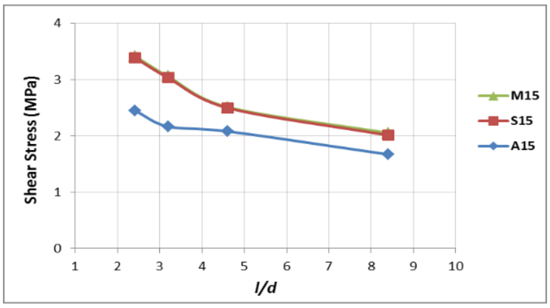


Figure (33): Effect of Opening Location with Size (0.15h x 0.15h)

### *D. Effect of Shear Span to Depth Ratio (a/d)*

Shear Strength of reinforced concrete Deep Beams Decreases when the Shear Span to Depth ratio is Increased, By increasing the shear span to depth ratio from (1 to 2.5)

for (l/d) between (2.42 and 8.4) and maximum size of aggregate of 9.5 reduces the shear stress by about (28.46%, 32.26% and 41.4%) for shear zone, support and mid-span opening locations respectively and (26.33%, 38.47%, 37.32%) for Sizes (0.45h x 0.45h), (0.30h x 0.30h) and (0.15h x 0.15h) respectively

While increasing the shear span to depth ratio from (1.5 to 2.25) for (l/d) of 4.61and maximum size of aggregate of 9.5 reduces the shear stress by about (4.7%, 5.43% and 12.03%) for shear zone, support and mid-span opening locations respectively and (7.01%, 7.39%, 7.76%) for Sizes (0.45h x 0.45h), (0.30h x 0.30h) and (0.15h x 0.15h) respectively, Figures (34) to (39) represents shear stress versus shear span to depth ratio (a/d) curves which used to show the effect of opening sizes and locations as follow:

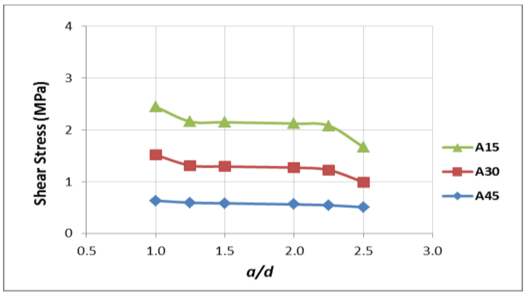


Figure (34): Effect of Opening Size at Shear zone

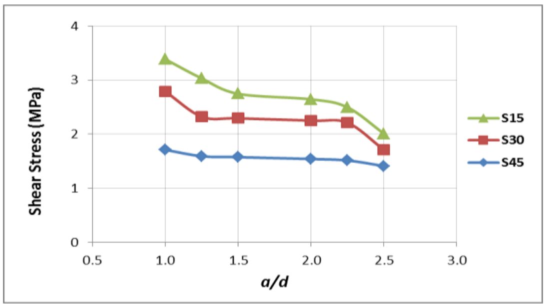


Figure (35): Effect of Opening Size at Support

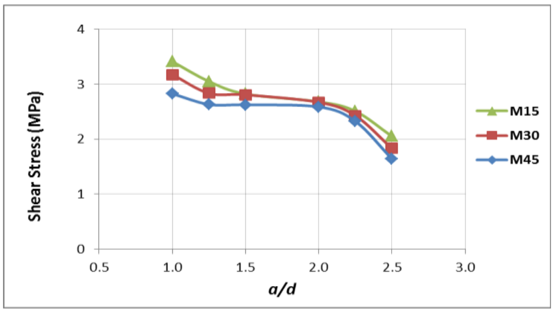


Figure (36): Effect of Opening Size at Mid span

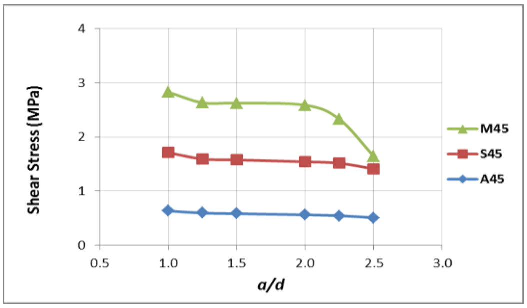


Figure (37): Effect of Opening Location with Size (0.45h x 0.45h)

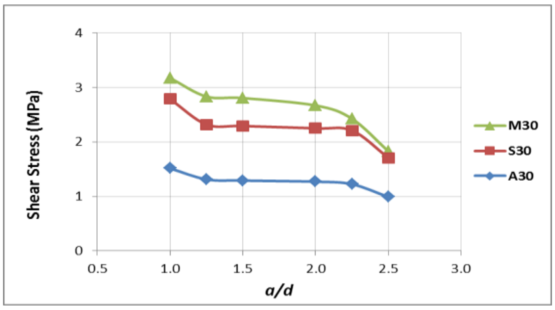


Figure (38): Effect of Opening Location with Size (0.30h x 0.30h)

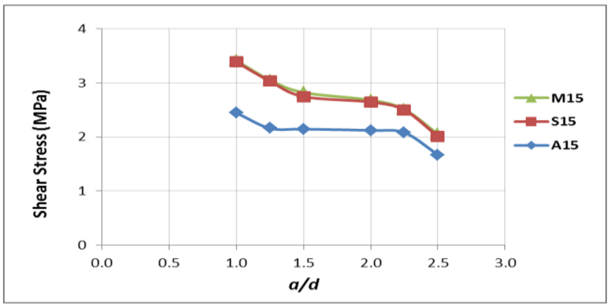


Figure (39): Effect of Opening Location with Size (0.15h x 0.15h)

### *E. Effect of Maximum Size of Coarse Aggregate*

Increasing maximum size of aggregate from 9.5 to 19 mm for (l/d) of 4.61 and (a/d) of 1.5 leads to a decrease in the ultimate shear stress by about (3.69%, 3.36% and 7.14%) for shear zone, support and mid-span opening locations respectively and (5.54%, 4%, 4.65%) for Sizes


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(0.45h x 0.45h), (0.30h x 0.30h) and (0.15h x 0.15h) respectively, Figures (40) to (45) represents shear stress versus maximum aggregate size curves which used to show the effect of opening sizes and locations as follow:

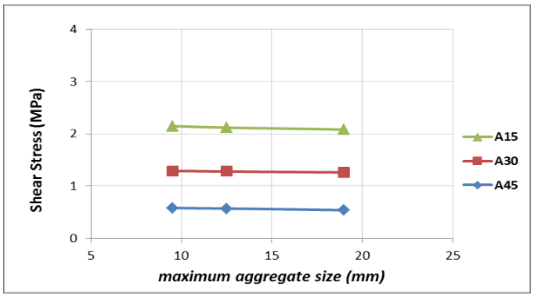


Figure (40): Effect of Opening Size at Shear zone

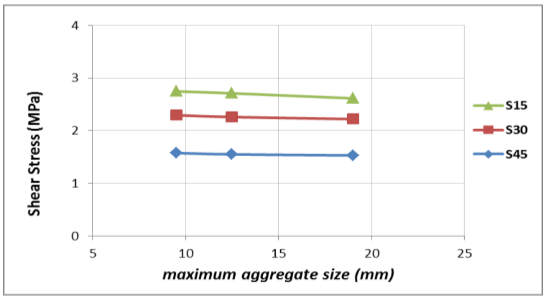


Figure (41): Effect of Opening Size at Support

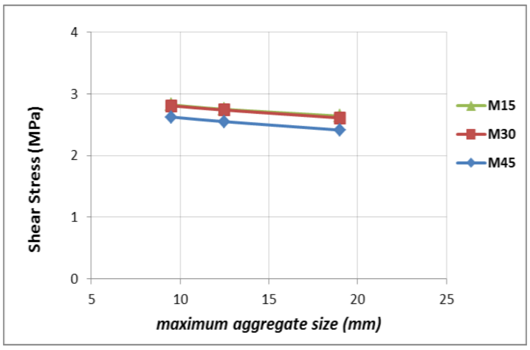


Figure (42): Effect of Opening Size at Mid span

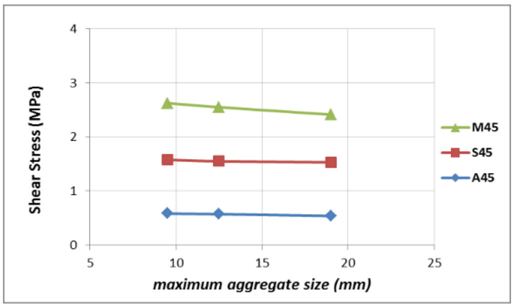


Figure (43): Effect of Opening Location with Size (0.45h x 0.45h)

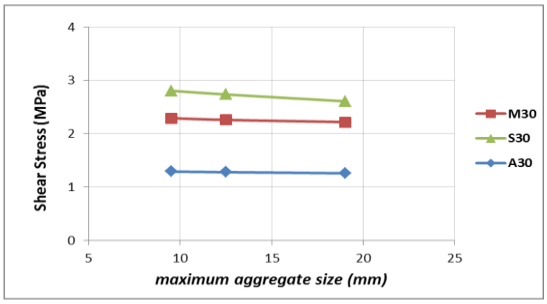


Figure (44): Effect of Opening Location with Size (0.30h x 0.30h)

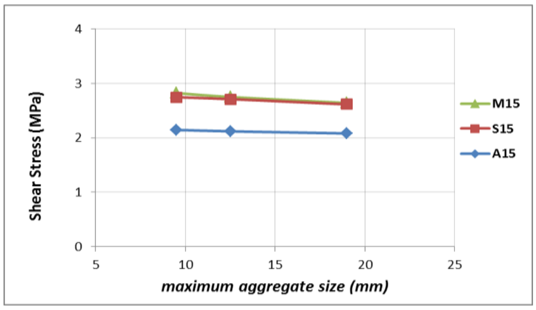


Figure (45): Effect of Opening Location with Size (0.15h x 0.15h)

## XI. CONCLUSIONS

On basis of the analysis carried out by using three-dimensional nonlinear finite element method with (Ansys+CivilFEM) computer program, the following conclusions can be made:

1- An experimental Study for Deep beams without Openings was used to validate the Results of (ANSYS+CivilFEM) program. a good agreement between the numerical and experimental results is observed with a difference reduction range of (6.4%) in Ultimate Shear Stress for all tested and analyzed beams.

2- Despite the complexity of the problem, which includes irregular stress pattern (due to the presence of the opening) The three dimensional nonlinear finite element model and the proposed simulation of the material in the present study are capable of Predicting the behavior of reinforced concrete Deep Beams with Openings of Different Sizes and Locations (Ansys+CivilFEM) software was found completely efficient in handling such analysis.

3- From the 99 deep beam with opening models the effect of parameters (l/d, a/d, fc and maximum size of aggregate) carried out conclusions as follow:

A) Shear Stress increased by decreasing (l/d, a/d, and maximum size of aggregate) but in different rates for each one depends on opening locations and sizes where increasing (l/d) ratio from 2.42 to 8.4 and (a/d) from 1 to 2.5 has high significant effect on the Shear strength


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B) increasing (a/d) from 1.5 to 2.25 for (l/d) of 4.61 has less effect on the average reduction of shear stress it was about (7.39%) for all sizes and locations while increasing maximum size of aggregate from 9.5mm to 19mm has very little effect where the average reduction in shear stress was (4.19%) for all Sizes and locations.

4- It can be noted that by increasing the compressive strength of concrete the ultimate Shear Strength is increased but in different rates for varied opening locations and sizes

5- By comparing the results of all 99 deep beam with opening models with the 11 deep beam without opening cases and from the effect of the parameters (l/d, a/d, fc, and maximum size of aggregate) figures (28) to (45) we concluded that:

A) The location of openings has a large effect, where this effect is the largest when openings location is at shear zone and a small effect when openings location is at mid-span.

B) It is found that the ultimate Shear increase with decrease for the size of openings therefore if the a designer has to provide an opening in a reinforced concrete deep beam, he should keep it in the Mid-span location with minimum possible Size but if there was a specific unavoidable size or location duo to architectural requirements the reductions in strength for each studied cases may be useful and it should be taken in consider.

## XII. SUGESTION FOR FURTHER WORK

1. Studying the shear strength of pre-stressed concrete deep beams with openings can be carried out by modifying the material model used in the present study.
2. Develop a design procedure for deep beam with openings which till now, no code pro-vision existed for design of such beams
3. Experimental study on the same models would be useful to get exact behavior then develop empirical equations for such cases of openings
4. Study shear strength behavior of deep beam with openings using different concrete types such as high strength concrete
5. Strengthening the models which showed little Shear strength with available external or internal strengthening processes. When the opening is planned before the construction and during the design stage Internal strengthening using steel bars around the opening in different patterns and quantities is suitable. While External strengthening using CFRP laminates around the opening in also different patterns and quantities procedure is beneficial when the opening is introduced after the construction, the case in which no analysis and design considerations where taken concerning the opening.

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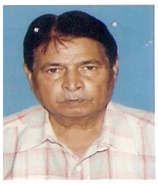

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